

Is there a gender difference in concussion incidence and outcomes?

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ABSTRACT

Objective: To determine if there is a gender difference in the incidence and outcomes of sport concussion.

Design: Critical literature review of sport concussion by gender.

Intervention: PubMed and major sports medicine journals were reviewed using the keywords concussion and gender. Articles included in this paper were English prospective surveillance that included concussion as an injury option conducted over the past 10 years, involved data collected by qualified medical personnel (athletic trainers/therapists or medical doctors) and used injury rates as opposed to raw counts. Only data from sports (soccer, basketball and ice hockey) where actions, equipment and most rules were similar between genders were reviewed.

Results: For the PubMed search, using “concussion” and “gender” as keywords, there were 51 articles. Ten studies (four in football (soccer), four in basketball and two in ice hockey, including high school, college and professional athletes) were included in the incidence portion of the paper. Nine of the studies showed higher absolute injury rates for female concussion compared to their male counterparts with four of them reaching statistical significance. Five of the studies (two football (soccer), two basketball and one ice hockey) examined concussion mechanism and in all cases, males had a higher absolute percent of player contact concussions while females had a higher absolute percentage of surface or ball contact concussion episodes. Two brain injury and four sport concussion outcome papers were reviewed. Traumatic brain injury outcome was shown to be worse in females than in males for a majority of measured variables; females also are shown to have different baseline and post-concussion outcomes on neuropsychological testing.

Conclusions: After evaluating multiple years of concussion data in comparable sports, the evidence indicates that female athletes may be at greater risk for concussion than their male counterparts. There also is some evidence that gender differences exist in outcomes of traumatic brain injury and concussions. Because concussion is a clinical diagnosis often depending on self reporting and with no established biological marker or consistent symptoms/definitions, and because there is evidence that females are more honest in reporting general injuries than males, it is unclear whether the concussion incidence data, while generally consistent in showing a higher risk in females as compared to males in similar sports, is a true difference or is influenced by a reporting bias.

Concussion in sports has received greater attention in the last decade as more is understood about the potential negative performance and health consequences of this injury. Ten years ago, an

estimated 300 000 sports-related traumatic brain injuries associated with loss of consciousness occurred annually in the USA.^{1,2} Given the greater understanding of concussion injury and its symptoms over the past decade, coupled with the significant increase in US and international youth sport participation, this number is significantly larger today. While much of the concussion research has been performed on males, the increasing participation of females in sports around the world warrants an analysis of their risk and response to concussion as well. For example in 2006–7, 42% (almost 3 million) of participating US high school³ and 43% (173 000) of participating NCAA⁴ student-athletes were female. The purpose of this review is to determine if a gender difference exists in sport concussion risk, symptoms and recovery. If such differences do exist, it raises the question as to whether current return to play guidelines need to consider gender as a specific factor influencing management decisions.

METHODS

A search of PubMed was performed using the keywords “concussion” and “gender” resulting in 51 articles found. The search was limited to English language publications and human studies. In addition, the main sports medicine journals and associated references were searched for additional papers regarding gender and sport concussion. The title and abstract of these articles were then reviewed by the author. The articles included in the incidence review were prospective surveillance that included concussion as an injury option conducted over the past 10 years, involved data collected by qualified medical personnel (athletic trainers/therapists or medical doctors) and used injury rates as opposed to raw counts. Some studies included injuries that involved no time loss although most required a reportable incident to have at least one day time loss. Only data from football (soccer), basketball and ice hockey were reviewed as these were sports where actions, equipment and most rules were similar between genders. In addition, two brain injury and four sport concussion outcome papers were reviewed.

RESULTS

Incidence studies

Ten prospective surveillance studies (four in football (soccer), four in basketball and two in ice hockey), involving high school, college and professional athletes were reviewed (table 1). Football (soccer) and basketball are both sports where

Table 1 Prospective injury surveillance studies evaluating concussion by comparable sport and gender

Sport	Reference	Study method	Subjects/activity	Study length/no. of schools	Higher concussion rate	Statistical difference	Approximate no. of concussions compared
Football (soccer)	7	Case control	PRO	6 yr, 20 tournaments	F (2.4 ×)	Not analysed	15
	6	Descriptive	HS,COL	1 yr, 100 schools	F	yes	40
	8, 9	Descriptive	COL	15 yr, 85 schools/yr	F	yes	400
	13	Cohort	HS	3 yr, 100 schools/yr	M	Not analysed	15
Basketball	5	Descriptive	HS	2 yr, 100 schools/yr	F (2 ×)	Not analysed	unknown
	6	Descriptive	HS,COL	1 yr, 100 schools	F	yes	35
	10, 11	Descriptive	COL	16 yr, 120 schools/yr	F	yes	200
	13	Cohort	HS	3 yr, 100 schools/yr	F	Not analysed	10
Ice hockey	14	Cohort	COL	1 yr, 6 schools	F	no	15
	15, 16	Descriptive	COL	4 yr, 20 schools/yr	F	no	100
			PG				

HS, high school; COL, college; F, female; M, male; PRO, professional; G, game; PG, practice and game.

action, rules and equipment are similar between genders so these confounding variables were minimised.

Ice hockey is a sport that has similar activities and equipment in the men's and women's game with one important rule distinction—intentional body checking is not allowed for females. Since player contact is a primary source of concussion in most sports, eliminating this mechanism implies that the risk of concussion would be significantly reduced in the women's game.

Nine of the studies showed higher absolute concussion injury rates for females compared to their male counterparts with four of them reaching statistical significance. An example of three college sports is shown in fig 1. In both ice hockey studies,

females had an absolute higher but statistically similar rate of concussion compared to their male counterparts despite the prohibition of intentional body checking in the women's game.

Concussion mechanism

A subset of the above studies reported concussion injury mechanism (table 2). In all cases, males showed an absolute higher percentage of player contact concussions while females showed absolute higher percentages in concussions resulting from contact with the surface or ball. Figures 2, 3 and 4 show specific examples of these results from three college sports.

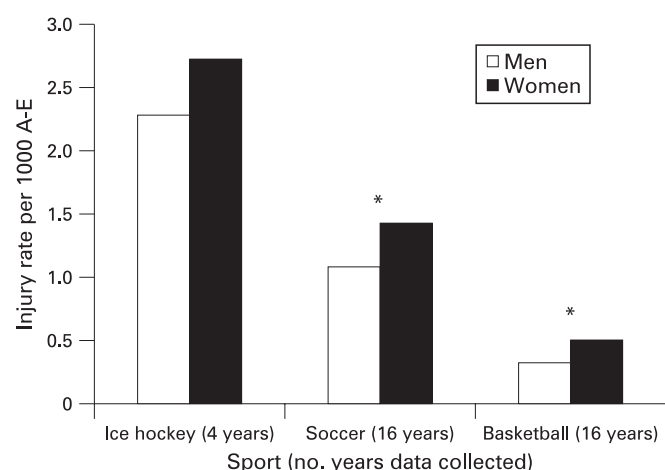


Figure 1 Game concussion rate by gender. The figure compares game concussion injury rates in basketball and soccer (similar rules and equipment) and ice hockey (similar equipment but different rules—no body checking allowed in women's game). In all three activities, the women's sports showed absolute rate values that were higher than their male counterparts and in two cases, (basketball and soccer), these rates were statistically higher.¹²

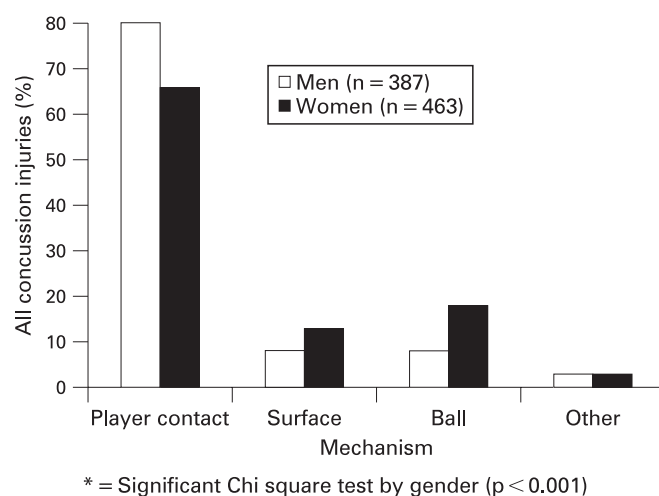
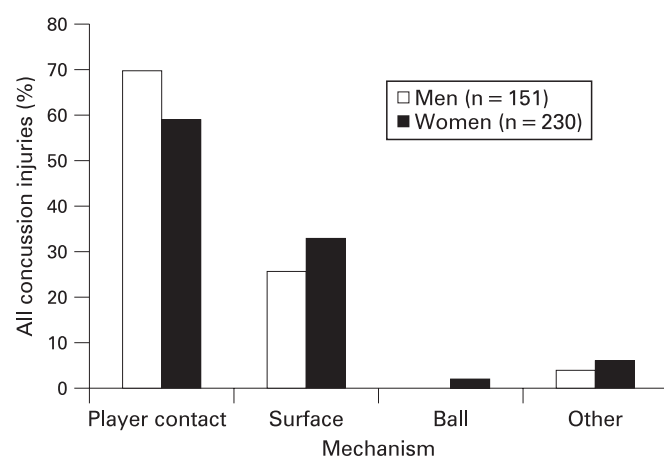


Figure 2 Soccer game concussion mechanism* by gender (1988–9 to 2003–4). The figure shows mechanism of concussion injury as a percent of all concussions in soccer. Exposures by gender were similar (<5% difference). There was a significant difference (p < 0.001) in concussion mechanism between genders. Specifically, there was a higher percentage of concussions resulting from player contact in men (81% vs 66%) and a higher percentage of concussion resulting from surface (13% vs 8%) or ball (18% vs 8%) contact in women.¹²

Supplement



† = Non-significant Chi square test by gender ($p = 0.059$)

Figure 3 Basketball game concussion mechanism by gender† (1988–9 to 2003–4). The figure shows mechanism of concussion injury as a percent of all concussions in basketball. Exposures by gender were similar (<5% difference). There was a similar pattern to football (soccer) but non-significant difference ($p = 0.059$) in concussion mechanism between genders. Specifically, there was a higher percentage of concussions resulting from player contact in men (70% vs 59%) and a slightly higher percentage of concussion resulting from surface contact in women (33% vs 26%).¹²

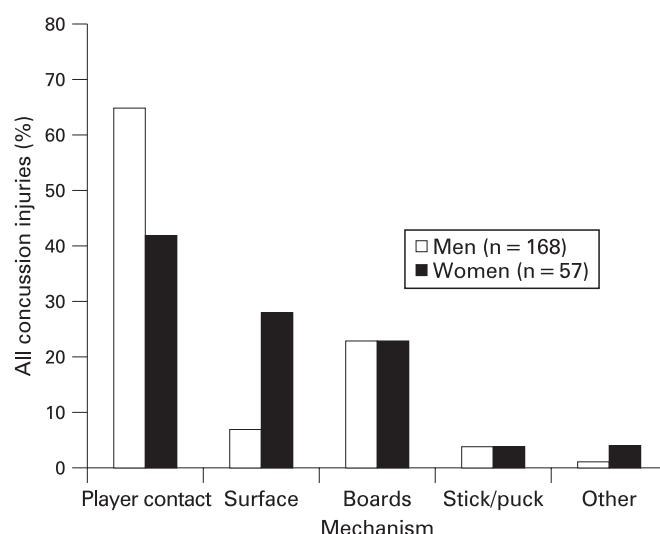
Gender differences in brain injury outcome

Evidence exists that indicates gender differences in outcomes of traumatic brain injury.

(a) A meta-analysis of eight studies with some limitations due to lack of specifics of individual reports, concluded that traumatic brain injury outcome was worse in women than in men for 85% of the 20 measured variables, which were primarily somatic symptoms such as poor memory, dizziness, fatigue, irritability in response to light and noise, impaired concentration, headache, anxiety and depression.¹⁷

(b) Gender has been shown to be an independent predictor of survival following brain injury. Mortality following moderate to severe traumatic brain injury was 1.28 times higher in females than males; furthermore females were 1.57 times more likely to experience poor outcomes (eg, severe disability or persistent vegetative state) than males.¹⁸

Specific to sports concussion, limited studies imply that females may be more frequently cognitively impaired than males following concussions. In a study by Broshek *et al*,¹⁹ using 155 concussed high school and college athletes, it was found that female athletes had significantly greater declines in simple and complex reaction times relative to preseason baseline levels, and they reported more post-concussion symptoms compared with age-matched males. As a group, females were cognitively



* = Significant Chi square test by gender ($p < 0.001$)

Figure 4 Ice hockey game concussion mechanism* by gender (2000–1 to 2003–4). The figure shows mechanism of concussion injury as a percent of all injuries in ice hockey where the basic game and equipment is similar between genders but rules restrict the use of formal body checking in the women's game. There was a significant difference ($p < 0.001$) in concussion mechanism between genders. Specifically, there was a higher percentage of concussions resulting from player contact in men (65% vs 42%) and a higher percentage of concussion resulting from contact with the ice surface (28% vs 7%) in women.¹²

impaired approximately 1.7 times more frequently than males following concussions.

Covassin *et al*²⁰ evaluated 79 collegiate sport concussions, almost equally distributed across males and females, collected from five universities. They identified post-concussion differences with regard to gender in only one of five cognitive domains of neuropsychological function. Specifically, concussed female athletes demonstrated significantly lower visual memory composite scores compared with male athletes. With respect to post-concussion symptoms, men reported post-concussion vomiting and sadness with greater frequency and intensity than women.

Complicating the post-concussion assessment, a study of over 1200 college age athletes showed that male and female athletes differed on baseline neuropsychological test measures, particularly on verbal and visual memory scores.²¹ A second study of high school athletes showed gender differences in baseline scores on selected measures of processing speed and executive functions.²²

DISCUSSION

Participation in physical activity offers many lifelong physical and mental benefits for both genders. However, with any

Table 2 Concussion mechanism by sport and gender

Sport	Reference	Level of participation	Study duration	Injury mechanism			
				Player contact	Surface	Ball/puck-stick	Boards
Football (soccer)	6	US college & high school	1 yr	M	F	F	NA
	8, 9	US college*	15 yr	M	F	F	NA
Basketball	6	US college & high school	1 yr	M	F	F	NA
	10, 11	US college	16 yr	M	F	F	NA
Ice hockey	15, 16	US college*	4 yr	M	F	similar	similar

NA, not applicable. Note: Gender (M-male, F-female) with highest % of each mechanism is reported. *Mechanism pattern significantly different by gender— χ^2 analysis ($p < 0.001$)

Table 3 Possible explanations for gender differences in sport concussions

Mechanism	Description
Biomechanical	Females have smaller head to ball ratios or weaker neck muscles ²³ ; less head/neck mass than males and increased head mass resulted in decreased linear acceleration ^{24, 25} ; Females exhibit greater angular acceleration of the head and neck. ²⁶
Cultural	US society more protective of female athletes. ²⁷ Cultural tendencies encourage male athletes to play despite injuries or to avoid reporting injuries; some boys suffering from head injuries may not report their symptoms for fear of being removed from play. ²⁸ A reluctance to report injury demonstrated in male high school American football players. ²⁹ Female athletes more concerned about the effects of an injury on their future health, and may be more honest in reporting and not as affected as male athletes when told they cannot participate. ³⁰
Hormonal	Oestrogen plays a protective role in males, and increase mortality in females. ³¹ Oestrogen can assist in maintaining normal cerebral blood flow, and actually decrease mortality when administered acutely. ³²

activity there are risks of injuries and in some cases these may be gender specific and need to be considered to maximise the benefits of athletic participation. After evaluating multiple years of concussion incidence data in comparable sports, the evidence indicates that female athletes may be at greater risk for concussion than their male counterparts. There also is limited evidence that gender differences exist in outcomes of traumatic brain injury and concussions although there is almost no physiological understanding behind this finding. Incidence findings were apparent in sports where rules and equipment were similar (football (soccer), basketball) as well as in ice hockey, where women's actual concussion rates were higher, though statistically not different than the men, despite the absence of the high risk activity of body checking. A subset of studies indicated that mechanism of concussion also may differ by gender. Specifically, limited studies show a greater susceptibility of women to concussion through contact with the surface or ball although there is no evidence that these specific events occur at the same frequency relative to males. There was only one study reviewed in this article¹³ and one study that was cited by multiple authors of the reviewed studies (based on retrospective recall that did not consider exposures²⁴) reporting a higher incidence in concussion in a male sport.

To date, very little research includes possible explanations for gender differences in sport concussion. The majority of applicable literature has focused on nonathletic populations (eg, accident victims) and rodents. Biomechanical and hormonal evidence exists that may explain mechanisms of gender difference. Another possibility is more cultural, founded on the premise that the honesty and responsiveness of reporting as opposed to the actual incidence of concussion may be influenced by gender (table 3).

Limitations

The prospective descriptive surveillance studies reviewed in this paper were designed to evaluate overall injury patterns and mechanisms in a sport, rather than specifically monitoring sport concussion. Subsequently, there were inconsistent definitions of reportable concussion and the concussion sample was often small and unbalanced by gender over a range of populations (high school to professional athletes). Because concussion is a clinical diagnosis often depending on self reporting and with no established biological marker or consistent symptoms/definitions, the incidence reported was most likely only a subset of

What is known on this topic

More sport concussions are being reported and studied as the awareness of symptoms and knowledge of potential negative performance and health consequences has increased. Most of the existing sport concussion research has been performed on males, despite the increasing participation of females in sport over the last two decades.

What this study adds

Female athletes may be at greater risk for concussion than their male counterparts. There also is limited evidence that gender differences exist in outcomes of traumatic brain injury and concussions. However, the existing data has significant limitations that warrant more concussion-focused research to validate these initial findings.

actual occurrences. If research indicating females are more honest in reporting injuries than males is applicable to concussions, it is difficult to definitively state that the concussion incidence differences between gender noted in this review are real; they may be in some part related to reporting bias. In addition, increased awareness, better assessment technology and more research in recent years imply that we are much better able to recognise sport concussions today compared to a decade ago. Therefore, changes in trends over time may be a reflection of actual concussion cases, a greater ability to identify concussion cases, or some combination.

CONCLUSION

After evaluating multiple years of concussion incidence data in comparable sports, the evidence indicates that female athletes may be at greater risk for concussion than their male counterparts. While definitions and assessment techniques for concussions have changed over the past decade, the consistent finding of higher concussion rates among women across studies coupled with increasing participation justifies the need for focused research efforts in risk factor identification and appropriate subsequent interventions. Reported gender variability in response to baseline and post-concussion neuropsychological testing suggests the gender variable may be more than a morbidity risk factor. Future studies should focus specifically on concussion risk, mechanism and subsequent symptoms and recovery for both genders in similar sports. Standardised definitions, assessments and symptoms and a mechanism to account for potential gender self-reporting bias should be the foundation of this work.

Competing interests: None.

REFERENCES

1. Sosin DM, Sniezek JE, Thurman DJ. Incidence of mild and moderate brain injury in the United States, 1991. *Brain Inj* 1996;**10**:47–54.
2. Centers for Disease Control and Prevention (CDC). Sports-related recurrent brain injuries—United States. *MMWR Morb Mortal Wkly Rep* 1997;**46**:224–7.
3. Participation in high school sports increases again; confirms NFHS commitment to stronger leadership. National Federation of State High School Associations. http://www.nfhs.org/web/2006/09/participation_in_high_school_sports_increases_again_confirms_nf.aspx (accessed 25 Feb 2009).

4. **NCAA sports sponsorship and participation rates report.** National Collegiate Athletic Association. <http://www.ncaapublications.com/ProductsDetailView.aspx?sku=PR2009> (accessed 17 Mar 2009).
5. **Borowski LA**, Yard EE, Fields SK, *et al.* The epidemiology of US high school basketball injuries, 2005-2007. *Am J Sports Med* 2008;**36**:2328-35.
6. **Gessel LM**, Fields SK, Collins CL, *et al.* Concussions among united states high school and collegiate athletes. *J Ath Train* 2007;**42**:495-503.
7. **Fuller CW**, Junge A, Dvorak J. A six year prospective study of the incidence and causes of head and neck injuries in international football. *Br J Sports Med* 2005;**39**(Suppl 1):i3-i9.
8. **Agel J**, Evans TA, Dick RW, *et al.* Descriptive epidemiology of collegiate men's soccer injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-89 Through 2003-04. *J Ath Train* 2007;**42**:270-7.
9. **Dick RW**, Putukian M, Agel J, *et al.* Descriptive epidemiology of collegiate women's soccer injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-89 through 2003-04. *J Ath Train* 2007;**42**:278-85.
10. **Dick RW**, Hertel J, Agel J, *et al.* Descriptive epidemiology of collegiate men's basketball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-89 through 2003-04. *J Ath Train* 2007;**42**:194-201.
11. **Agel J**, Olson DE, Dick RW, *et al.* Descriptive epidemiology of collegiate women's basketball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-89 through 2003-04. *J Ath Train* 2007;**42**:202-10.
12. **Dick RW**, Agel J, Hootman JM, *et al.* Concussion rates and gender in NCAA competitions. *Med Sci Sports Exerc* May 2008;**40**(Suppl 1):S231.
13. **Schulz MR**, Marshall SW, Mueller FO, *et al.* Incidence and risk factors for concussion in high school athletes, North Carolina, 1996-1999. *Am J Epidemiol* 2004;**160**:937-44.
14. **Schick DM**, Meeuwisse WH. Injury rates and profiles in female ice hockey players. *Am J Sport Med* 2003;**31**:47-52.
15. **Agel J**, Dompier TP, Dick RW, *et al.* Descriptive epidemiology of collegiate men's ice hockey injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-89 through 2003-04. *J Ath Train* 2007;**42**:241-8.
16. **Agel J**, Dick RW, Nelson B, *et al.* Descriptive epidemiology of collegiate women's ice hockey injuries: National Collegiate Athletic Association Injury Surveillance System, 2000-01 through 2003-04. *J Ath Train* 2007;**42**:249-254.
17. **Farace E**, Alves WM. Do women fare worse? A metaanalysis of gender differences in outcome after traumatic brain injury. *Neurosurg Focus* 2000;**8**:e8.
18. **Kraus JF**, Peek-Asa C, McArthur D. The independent effect of gender on outcomes following traumatic brain injury: a preliminary investigation. *Neurosurg Focus* 2000;**8**:e5.
19. **Broshek DK**, Kaushik T, Freeman JR, *et al.* Sex differences in outcome following sports-related concussion. *J Neurosurg* 2005;**102**:856-63.
20. **Covassin T**, Swanik CB, Schatz P. Sex differences in neuropsychological function and post-concussion symptoms of concussed collegiate athletes. *Neurosurgery* 2007;**61**:345-51.
21. **Covassin T**, Swanik CB, Sachs M, *et al.* Sex differences in baseline neuropsychological function and concussion symptoms of collegiate athletes. *Br J Sports Med* 2006;**40**:923-7.
22. **Barr WB**. Neuropsychological testing of high school athletes: preliminary norms and test-retest indices. *Arch Clin Neuropsych* 2003;**18**:91-101.
23. **Barnes BC**, Cooper L, Kirkendall DT, *et al.* Concussion history in elite male and female soccer players. *Am J Sports Med* 1998;**26**:433-8.
24. **Queen RM**, Weinhold PS, Kirkendall DT, *et al.* Theoretical study of the effect of ball properties on impact force in soccer heading. *Med Sci Sports Exerc* 2003;**35**:2069-76.
25. **Mansell J**, Tierney RT, Sitler MR, *et al.* Resistance training and head-neck segment dynamic stabilization in male and female collegiate soccer players. *J Athl Train* 2005;**40**:310-19.
26. **Tierney RT**, Sitler MR, Swanik CB, *et al.* Gender differences in head-neck segment dynamic stabilization during head acceleration. *Med Sci Sports Exerc* 2005;**37**:272-9.
27. **Vertinsky PA**. *The eternally wounded woman: women, doctors, and exercise in the late nineteenth century*. Urbana, IL: University of Illinois Press, 1994:1-7.
28. **Lovell MR**, Collins MW, Maroon JC, *et al.* Inaccuracy of symptom reporting following concussion in athletes [abstract]. *Med Sci Sports Exerc* 2002;**34**(suppl 1):S298.
29. **McCrea M**, Hammeke T, Olsen G, *et al.* Unreported concussion in high school football players: implications for prevention. *Clin J Sport Med* 2004;**14**:13-17.
30. **Granite V**, Carroll J. Psychological response to athletic injury: Sex differences. *J Sport Behav* 2002;**25**:243-59.
31. **Emerson CS**, Headrick JP, Vink R. Estrogen improves biochemical and neurologic outcome following traumatic brain injury in male rats, but not in females. *Brain Res* 1993;**8**:95-100.
32. **Roof RL**, Hall ED. Estrogen-related gender differences in survival rate and cortical blood flow after impact acceleration head injury in rats. *J Neurotrauma* 2000;**17**:367-88.